U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-286 199

Control of Volatile Organic Emissions from Existing Stationary Sources. Volume VII Factory Surface Coating of Flat Wood Paneling

Pacific Environmental Services, Inc, Santa Monica, CA

Prepared for

Environmental Protection Agency, Research Triangle Park, NC

Jun 78

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/2-78-032
OAQPS No. 1.2-112
June 1978

Air

PB 286 199

EPA

Guideline Series

Control of Volatile Organic Emissions from Existing Stationary Sources Volume VII: Factory Surface Coating of Flat Wood Paneling

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/2-78-032	2.
3. RECIPIENT'S ACCESSION NO. PB286199	
4. TITLE AND SUBTITLE Control Of Volatile Organic Emissions from Existing Stationary Sources - Volume VII: Factory Surface Coating of Flat Wood Paneling	5. REPORT DATE June 1978
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Roy R. Sakaida	8. PERFORMING ORGANIZATION REPORT NO. OAQPS No. 1-2.112
9. PERFORMING ORGANIZATION NAME AND ADDRESS Pacific Environmental Services, Inc. 1930 14th Street Santa Monica, California 90404	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air and Waste Management Office of Air Quality Planning and Standards Research Triangle Park, North Carolina 27711	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

This document provides guidance for development of regulations to limit emissions of volatile organic compounds from the factory surface coating of flat wood panels. This guidance includes emission limits for three categories of panels which represents Reasonably Available Control Technology (RACT) for these operations. The industry is described, methods for reducing organic emissions are reviewed, and monitoring and enforcement aspects are discussed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Flat Wood Panel Finishing Emission Limits Regulatory Guidance	Air Pollution Control Stationary Sources Organic Vapors	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Unlimited	Unclassified	66
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	HC4-HC1

EPA Form 2220-1 (9-73)

EPA-450/2-78-032
OAQPS No. 1.2-112

Control of Volatile Organic Emissions from Existing Stationary Sources - Volume VII: Factory Surface Coating of Flat Wood Paneling

Emission Standards and Engineering Division
Chemical and Petroleum Branch

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1978

1.a

OAQPS GUIDELINE SERIES

The guideline series of reports is being issued by the Office of Air Quality Planning and Standards (OAQPS) to provide information to state and local air pollution control agencies; for example, to provide guidance on the acquisition and processing of air quality data and on the planning and analysis requisite for the maintenance of air quality. Reports published in this series will be available - as supplies permit - from the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, or, for a nominal fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

Publication No. EPA-450/2-78-032
(OAQPS No. 1.2-112)

This report is based largely on information developed under contract by Pacific Environmental Services, Inc. (Contract No. 68-02-2606, Task No. 4) Conclusions and recommendations were prepared by EPA staff.

PREFACE

This is one in a series of reports designed to assist State and local jurisdiction in the development of air pollution control regulations for surface coating industries. The series is directed entirely at volatile organic compounds (VOC) which contribute to the formation of photochemical oxidants.

Volume I, "Control Methods for Surface Coating Operations," EPA-450/2-76-028 (OAQPS No. 1.2-067), November 1976, provides general information on the cost and effectiveness of control technology and guidelines for sampling and analyzing VOC emissions.

Volume II (EPA-450/2-77-008, May 1977), provides specific information on five surface coating industries; namely, automobile and light duty truck, can,coil, fabric, and paper coating operations. For each industry, coating systems are reviewed and various VOC control alternatives are considered with their costs and limitations. Volume II also provides guidance on the preparation of air pollution control regulations and test methodology suitable for their enforcement (Appendixes A and C of Volume II). Volumes III, IV, and V cover magnet wire coating, large appliance and metal furniture manufacture.

It must be cautioned that the limits provided in the table are based on capabilities and characteristics which are general and therefore presumed normal to the flat wood industries; the limits may not be applicable to every plant within the industry.

In each case, the recommended limitation is stated in terms of the total solvent content of all the coatings applied to a specific area of finished paneling product. This form is most applicable to situations where low solvent coatings are employed. If an operator should choose to comply by installation of add-on control devices, it may be appropriate for the agency to set minimal requirements on the hooding or capture and the efficiency of the control device.

The table that follows provides emission limitations that represent the presumptive norm that can be achieved through the application of reasonably available control technology (RACT). RACT is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. It may require technology that has been applied to similar, but not necessarily identical source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source. This does not, however, preclude requiring a short-term evaluation program to permit the application of a given technology to a particular source. The latter is an appropriate technology-forcing aspect of RACT.

The recommended emission limits are stated in terms of kg of VOC per 100 square meters of coated surface (lbs per 1000 square feet) to give operators necessary flexibility in adjusting the VOC content of the various coatings applied to a given panel. Practices vary such that it would be difficult to set a VOC limit for each type of coating. By balancing the VOC content and properties of the various coats, acceptable VOC

reductions can be achieved without sacrificing product quality.

FACTORY FINISHED PANELING

Product Category	Recommended Limitation	
	kg of VOC per 100 sq meters of coated surface	lbs of VOC per 1,000 sq ft of coated surface
Printed interior wall panels made of hardwood plywood and thin particleboard	2.9	6.0
Natural finish hardwood plywood panels	5.8	12.0
Class II finishes for hardboard paneling	4.8	10.0

For printed interior panels, emission limits are based on partial use of water-borne and solvent-borne coatings. Water-borne coatings that produce products of acceptable quality are not available for all coatings, particularly clear topcoats and printing inks. For natural finish paneling, the limits are based on use of solvent based coatings of lower solvent content than conventional coatings. The number of coats and coverage of coatings vary but (for typical usage) the recommended limitations are equivalent to usage of coatings which have average VOC contents of 0.20 kg/l (1.7 lbs/gal) for printed hardwood paneling, 0.38 kg/l (3.2 lbs/gal) for natural finish paneling, and 0.32 kg/l (2.7 lbs/gal) for Class II finishes for hardboard paneling.

Interior printed wall paneling is made from tropical hardwood plywood (and a few domestic hardwoods) and from thin particleboard. Natural finish hardwood plywood is made from domestic hardwoods. Class II finishes for hardboard are used for printed wall paneling and panels for other interior uses.

The other significant categories of factory finished flat wood products - exterior siding, tileboard, and particleboard used as a furniture component are not reviewed in this document nor are emission limitations suggested.

GLOSSARY

Printed panels means panels whose grain or natural surface is obscured by fillers and basecoats upon which a simulated grain or decorative pattern is printed.

Hardwood plywood is plywood whose surface layer is a veneer of hardwood.

Particleboard is a manufactured board made of individual wood particles which have been coated with a binder and formed into flat sheets by pressure. Thin particleboard has a thickness of one-fourth inch or less.

Natural finish hardwood plywood panels means panels whose original grain pattern is enhanced by essentially transparent finishes frequently supplemented by fillers and toners.

Hardboard is a panel manufactured primarily from inter-felted ligno-cellulosic fibers which are consolidated under heat and pressure in a hot-press.

Class II hardboard paneling finishes means finishes which meet the specifications of Voluntary Product Standard PS-59-73 as approved by the American National Standards Institute.

Lauan is an imported tropical hardwood.

CONVERSION FACTORS FOR METRIC UNITS

Metric Unit	Metric Name	Equivalent English Unit
Kg	kilogram (10^3grams)	2.2046 lb
liter	liter	0.0353 ft^3
m	meter	3.28 ft
m^3	cubic meter	35.31 ft^3
Mg	megagram (10^6grams)	2,204.6 lb
metric ton	metric ton (10^6grams)	2,204.6 lb

In keeping with U.S. Environmental Protection Agency policy, metric units are used in this report. These units may be converted to common English units by using the above conversion factors.

Temperature in degrees Celsius (C^o) can be converted to temperature in degrees Farenheit (^oF) by the following formula:

$$t^o_f = 1.8\ (t^o_c) + 32$$

t^o_f = temperature in degrees Farenheit

t^o_c = temperature in degrees Celsius or degrees Centrigrade

TABLE OF CONTENTS

Section		Page
1.0	SOURCES AND TYPES OF EMISSIONS	1-1
1.1	General Discussion.	1-1
1.2	Flat Wood Products and Coatings	1-4
1.2.1	Flat Woods and Products.	1-4
1.2.2	Flat Wood Coatings	1-5
1.3	Flat Wood Coating Processes	1-6
1.3.1	Coating Application Methods.	1-6
1.3.2	Process Description.	1-9
1.4	Sources and Types of Emissions.	1-15
	References for Section 1.0	1-17
2.0	APPLICABLE SYSTEMS OF EMISSION REDUCTION	2-1
2.1	Add-on Devices.	2-1
2.1.1	Incineration	2-1
2.1.2	Adsorption	2-2
2.2	Materials Changes	2-2
2.2.1	Water-borne Coatings	2-2
2.2.2	High Solids Coatings	2-6
2.3	Process Changes	2-6
2.3.1	Ultraviolet Curing	2-6
2.3.2	Electron Beam Curing	2-7
2.4	Control Levels.	2-7
2.4.1	Printed Interior Wall Paneling	2-8
2.4.2	Natural Hardwood Plywood Interior Paneling	2-8
	References for Section 2.0	2-9
3.0	COSTS AND ANALYSES OF CONTROL OPTIONS.	3-1
3.1	Introduction.	3-1
3.1.1	Purpose.	3-1
3.1.2	Scope.	3-1
3.1.3	Use of Model Plants.	3-1
3.1.4	Bases for Estimates of Capital Costs	3-2
3.1.5	Bases for Annualized Cost Estimates.	3-3

TABLE OF CONTENTS (Concluded)

Section		Page
3.2	Control of Solvent Emissions.	3-4
3.2.1	Retrofit Costs of Water-Borne Systems. . . .	3-4
3.2.2	Operation of a Water-Borne System.	3-5
3.2.3	Retrofit Costs of Ultraviolet/Water-Borne Systems.	3-5
3.2.4	Operation of an Ultraviolet/Water-Borne System	3-5
3.2.5	Net Annualized Cost.	3-7
3.3	Cost-Effectiveness Analysis	3-7
	References for Section 3.0	3-11
4.0	EFFECTS OF ACHIEVING EMISSION LEVELS REPRESENTATIVE OF RACT	4-1
4.1	Water-Borne Systems	4-1
4.2	Ultraviolet-Curable Coatings.	4-2
5.0	MONITORING TECHNIQUES AND ENFORCEMENT ASPECTS.	5-1
	References for Section 5.0	5-3
APPENDIX A	DETERMINATION OF VOC IN COATINGS.	A-1
APPENDIX B	CALCULATIONS OF EMISSION RATES AND REDUCTIONS	B-1
APPENDIX C	EFFECT OF DEPRECIATION AND TAXES.	C-1

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Simplified Schematic of Roll Coaters.	1-7
1-2	Pressure Head Curtain Coater.	1-8
1-3	Printed Interior Paneling Line (Lauan, Hardboard, and Particleboard).	1-10
1-4	Natural Hardwood Plywood Interior Paneling Line	1-13
3-1	Cost Effectiveness for VOC Control at Existing Printed Panel Coating Plants.	3-10

LIST OF TABLES

Table		Page
1-1	Flat Wood Plants.	1-2
1-2	Flat Wood Coatings.	1-16
2-1	Volatile Organics in Flat Wood Coatings	2-4
2-2	Sample Estimation of VOC Emissions for Interior Printed Panels.	2-5
3-1	Cost Factors Used for Computing Annualized Costs. . . .	3-6
3-2	Net Annualized Cost Estimates	3-9
C-1	Computation of Present Value Tax Savings.	C-3

1.0 SOURCES AND TYPES OF EMISSIONS

1.1 GENERAL DISCUSSION

Prefinished flat wood construction products included in this document are interior paneling made of wood materials such as plywood, particleboard, and hardboard.

Plywoods are assemblies of layers of veneer or veneer in combination with a lumber core which are joined together with an adhesive. Particleboards are panels manufactured from discrete pieces or particles of lignocellulosic materials (usually wood) with added binder. Particleboards with different properties are produced by the addition of other materials and by manufacturing process variations. Hardboards are panels manufactured from wood (usually) or other vegetable fibers to which other materials are added to improve product properties; the panels are then consolidated under heat and pressure to a density of at least 31 lb/ft^3.

Although plants which handle these flat woods are located throughout the United States, the Pacific Coast and the southern States have the largest numbers (Table 1-1). Listings from the 1976 Directory of Panel Plants-U.S.A.[1] and from several wood products associations,[2-8] along with direct phone contacts, were used to compile the plant numbers. Hardwood plywood prefinishers[7] and converters of hardboard[8] are included in the plant numbers. These numbers are intended to give an indication of the general regional distribution of plants which handle flat woods and are not intended to provide exact numbers of coaters or flat wood plants.

However, the overall differences between the numbers of plants shown in Table 1-1 and those given in the 1972 Census of Manufacturers[9] are relatively minor, except for hardwood plywood

Table 1-1. FLAT WOOD PLANTS[a]
(Fabricates/Converts/Coats)

State	Hardwood Plywood	Softwood Plywood	Particle-board	Hard-board
Connecticut	1	0	0	0
Maine	2	0	0	0
New Hampshire	2	1	0	0
Vermont	4	0	0	0
New Jersey	4	0	0	4
New York	4	0	0	1
Pennsylvania	2	0	2	1
Florida	7	1	1	2
Georgia	10	6	3	4
Maryland	0	1	0	0
North Carolina	28	5	6	4
South Carolina	16	3	2	2
Virginia	18	3	5	3
West Virginia	1	0	1	0
Alabama	9	6	4	0
Kentucky	5	0	2	0
Mississippi	7	6	4	3
Tennessee	14	0	1	2
Arkansas	3	11	5	2
Louisiana	4	12	4	2
Oklahoma	0	1	1	1
Texas	6	11	6	3
Illinois	4	1	0	1
Indiana	9	0	1	1
Michigan	9	1	1	1
Ohio	2	0	0	0
Wisconsin	19	0	1	3
Iowa	0	0	0	0
Minnesota	2	0	2	2
Missouri	2	0	0	1
Arizona	0	0	1	0
Colorado	0	1	0	0
Idaho	3	5	1	1
New Mexico	0	0	1	0
Montana	0	7	1	1
California	24	25	9	7
Oregon	16	98	14	12
Washington	10	35	1	3

[a] Source: References 2-8 and direct contacts.

plants, for which the census data show significantly larger numbers in Indiana and North Carolina and smaller numbers in the Pacific States.

Statistical information concerning the flat woods industry as a whole can be obtained under the following Standard Industrial Classifications (SIC):

2431 - Millwork, doors, moulding
  24314 - Wood doors
2435 - Hardwood veneer and plywood
2436 - Softwood veneer and plywood
2492 - Particleboard
2499 - Wood, not elsewhere classified
  24996 - Hardboard

No more than one quarter of the flat wood manufacturers discussed herein are estimated to coat in their plants. In some of the plants that do coat, only a small percentage of the total production capacity is coated. In addition to manufacturing plants, there are intermediate plants, which obtain unfinished products and prefinish or finish them according to their customers' specifications or product requirements.

Based on membership information from the several wood product associations (which are not all inclusive), approximately 40 percent of the hardwood plywood handling plants coat,[5,6] 10 percent of the softwood plywood plants coat,[6] and under 15 percent of the particleboard plants coat. The American Board Products Association estimates that 70 percent or more of the hardboard manufactured is factory coated in some fashion.

It appears that there will be an increase in the factory surface coating of flat wood products due to the increased use of prefinished wood in the building trade (including recreational

vehicles) for paneling, flooring, cabinetry, moulding, and exterior siding (only paneling is covered in this report). Reasons given for this increase are:

- Cost savings
- Uniform and better quality finish
- Longer life finish

Control of emissions of volatile organic solvents from the factory coating of flat wood products by add-on devices is not being practiced to any great extent. Many coaters are using solvents which were previously assumed to be of low photochemical reactivity and were therefore considered exempt.* Others have been converting to water-borne coatings where possible. Coatings manufacturers and certain wood coaters are continuing efforts to develop useful water-borne coatings with reduced quantities of volatile organics.

1.2 FLAT WOOD PRODUCTS AND COATINGS

1.2.1 FLAT WOODS AND PRODUCTS

Flat woods discussed herein include products from hardwood plywood, particleboard (products not used in cabinetry and furniture), and hardboard. Product categories considered are:

- Printed interior paneling
- Natural hardwood plywood interior panels

Printed interior panelings are produced from plywoods with hardwood surfaces (primarily lauan) and from various wood composition panels, including hardboard and particleboard. Finishing techniques are used primarily to cover the original surfaces;

---

* The only VOC recommended as exempt are: methane, ethane, 1,1,1-trichloroethane (methyl chloroform), and trichlorotrifluoroethane (Freon 113).[10]

they also function to produce various decorative surfaces, which include wood patterns, simulations of other natural materials, and original decorative effects.

Natural hardwood plywood interior panels are prefinished to enhance and protect their natural appearance. Almost all the finishes applied are essentially clear. Possible exceptions include coatings for the grooves that may be cut into the panel and stains or toners used to complement the natural wood grain.

1.2.2 FLAT WOOD COATINGS

All coatings which can be applied to a flat wood substrate can be factory applied. These include but are not limited to filler, sealer, groove coat, primer, stain, basecoat, inks, and topcoat. Fillers are used to fill pores, voids, and cracks in the wood to provide a smooth surface; they can also accentuate the grain of natural hardwood veneers. Sealers seal off substances in the wood which may affect subsequent finishes as well as protect the wood from moisture. Groove coats cover grooves cut into the panel to assure that the grooves are compatible with the final surface color. Primers are used to protect the wood from moisture and to provide a good surface for further coating applications. Stains are nonprotective, coloring the wood surface without obscuring the grain. Basecoats are the primary coating/coloring of panels and normally should completely hide substrate characteristics. Inks are used to put a decorative design on printed panels; they can also produce special appearances on natural hardwood plywoods. Topcoats provide protection, durability, and the required sheen or gloss to the product.

Each type of substrate coated and product category handled usually requires a different coating formulation for each

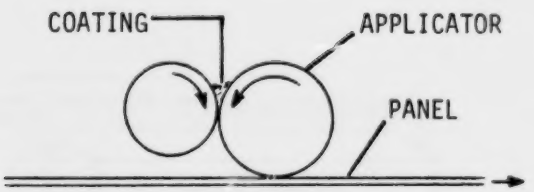
appropriate coating application. Moreover, not all factory wood products with the same substrate and prefinished for the same end use have the same series of coatings applied.

1.3 FLAT WOOD COATING PROCESSES

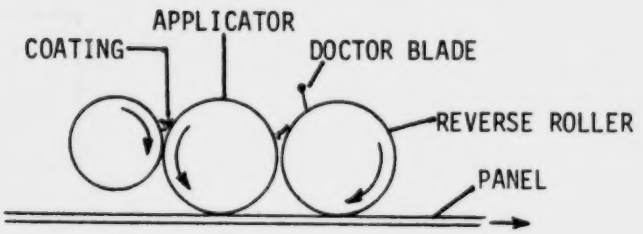
1.3.1 COATING APPLICATION METHODS

Different forms of roll coating are the favored procedures for applying coatings to flat woods. Roll coating is a process in which coating is applied to the wood by cylindrical rollers (Figure 1-1). If the applicator rotates in the same direction as the panel movement, the coater is called a direct roll coater. Most coatings (primer, sealer, basecoat, topcoat, and other coatings used for surface coverage) can be applied with a direct roll coater. When the applicator roll is followed by a wiper roll that rotates against the direction of the panel movement, the process is called reverse roll coating. Reverse roll coaters are generally used to apply filler, which is forced into the voids and cracks in the panels by the reverse roller. Precision coating and printing are also forms of roll coating. The applicator roll shown in Figure 1-1 is used to place the ink or coating onto a second roll (engraved for printing) on which the coating thickness is monitored; the coating is then passed to a final roller which coats the wood.

Several types of curtain coaters are also used. In this method, the panel passes through a free-falling film of coating. In a pressure head curtain coater (Figure 1-2), coating material is metered into a pressure head, then forced through a calibrated slit between two knives. The rate of panel movement and the controlled uniform flow of the film determines the coating thickness. The physical properties of the material, temperature, slit width, coating flow rate, and panel speed are important variables.



A. DIRECT ROLL COATER



B. REVERSE ROLL COATER

Figure 1-1. Simplified Schematic of Roll Coaters

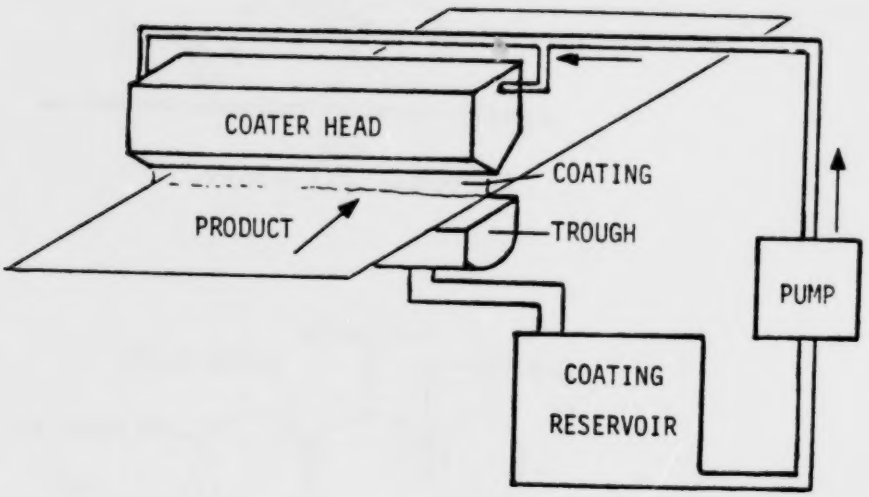


Figure 1-2. Pressure Head Curtain Coater

All excess coating is caught in a trough and recirculated. Additional coating methods include various spraying techniques and brush coating.

1.3.2 PROCESS DESCRIPTION

The flow diagrams that accompany the following process descriptions are general, showing some but not all typical production line variations. Product categories included are printed interior paneling and natural hardwood plywood interior paneling.

1.3.2.1 Printed Interior Paneling (Lauan, Hardboard, and Particleboard)

Printed interior paneling products are the result of applying a decorative finish to the surface of lauan, hardboard, or particleboard. Substrates are often presanded by the flat wood manufacturer prior to delivery to the intermediate coating plant or in-house coating line. The basic series of coatings applied consists of filler, basecoat, inks, and topcoat (Figure 1-3).

The first step in finishing hardboard consists of tempering the board with a mixture of oil and resin to give it added strength and stability. This is followed by brush dusting to remove any foreign matter from the surface of the board. For particleboard, on the other hand, the first step in the finishing process is sanding (refer to Figure 1-3).

Groove cutting is usually done prior to filling. Groove color can be applied in different ways and at different points in the coating procedure; in Figure 1-3, it is shown preceding the application of filler. Groove coats are usually pigmented, low resin solids that are reduced with water prior to use.

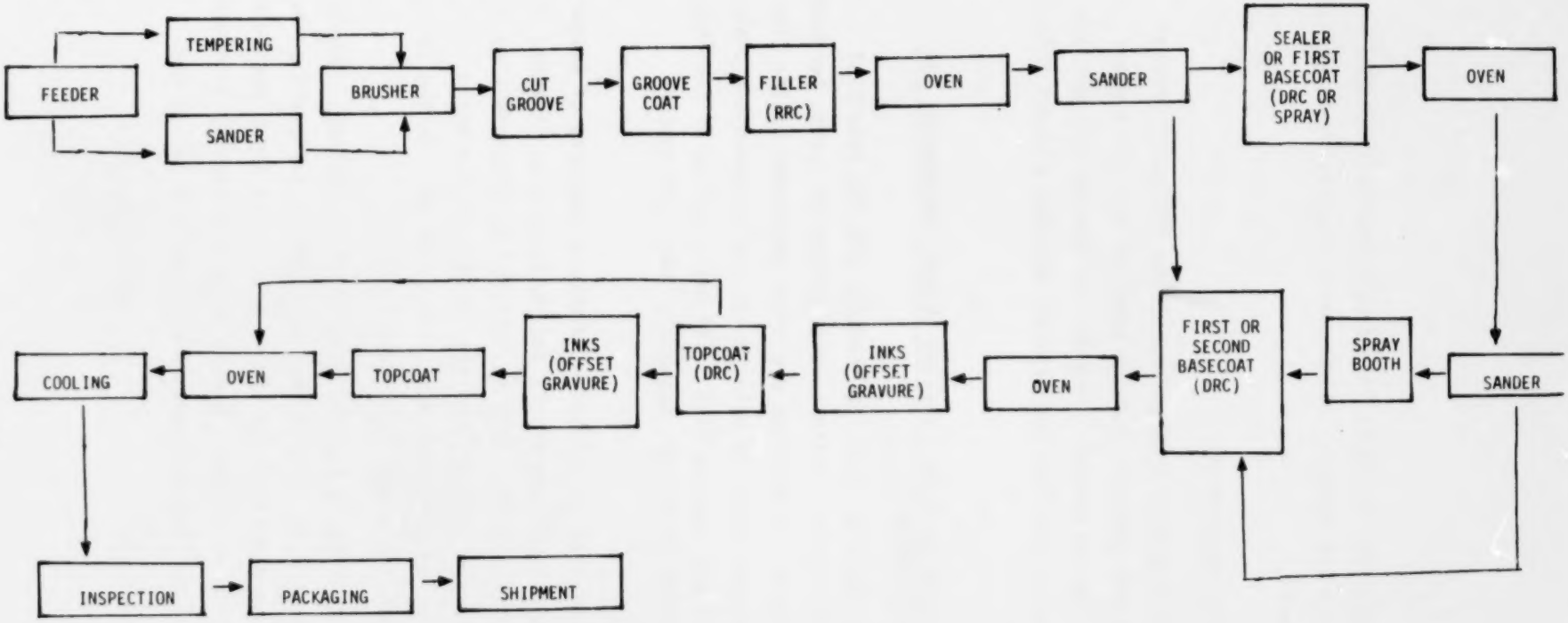


Figure 1-3 Printed Interior Paneling Line (Lauan. Hardboard and Particleboard)

Filler is normally applied by reverse roll coating. Fillers must dry fast, be easily sanded, seal the board (especially if no separate sealer is applied), and not shrink with age. Several different fillers, each with various advantages and disadvantages, are available: (1) polyester filler, which is ultraviolet-cured, (2) water-based filler, (3) lacquer-based filler, (4) polyurethane filler, and (5) alkyd urea-based filler. Water-based fillers are in common use on printed paneling lines. Filler is of course not applied to prefilled particleboard and to boards that can successfully remain nonfilled. It can be applied more than once to assure complete coverage of particularly porous substrates, and is followed by application of a separate sealing compound when necessary. The sealer may be water- or solvent-based, and is usually applied by airless spray or direct roll coating, respectively. Both filling and sealing operations are followed by ovens (steam heated, convection, infrared, or ultraviolet, as applicable) and by sanders. In hardboard finishing, the next step may consist of a spray booth where specialty coatings for textured board are applied.

For printed paneling, the purpose of the basecoat is to provide a smooth surface of the appropriate color on which to print the wood grain or other pattern. Basecoats must therefore be fast drying and provide good coverage. Those used in printed paneling usually fall into the following categories: lacquer, synthetic, vinyl, modified alkyd urea, catalyzed vinyl, and water-based (which are now used at some lauan finishing plants). Basecoats are usually applied by direct roll coaters.

Inks are applied by an offset gravure printing operation similar to direct roll coating. Several colors may be applied in order to reproduce the appearance of wood, marble, leather, textured cloth, and so on. The final effect depends on surface

smoothness, color of the basecoat and inks, strength and transfer properties of the inks, and other variables. Most lauan printing inks are pigments dispersed in alkyd resin, with some nitrocellulose added for better wipe and printability. Water-based inks have a good future for clarity, cost and ecological reasons.

After printing, the board goes through one or two direct roll coaters for application of the clear, protective topcoat. These are wet-on-wet applications, usually employing three-roll precision roll coaters. Some topcoats are now synthetic, prepared from solvent soluble alkyd or polyester resins, urea formaldehyde cross linkings, resins, and solvents. Such synthetic topcoats are catalyzed and sent through a hot air oven for curing; other topcoats are cured in infrared or ultraviolet ovens. The panels are cooled prior to stacking, inspection, and shipping.

1.3.2.2 Natural Hardwood Plywood Interior Paneling

Hardwood plywood has a face ply of hardwood veneer. The woods used are classified as porous or open grain species and nonporous or smooth species. Natural hardwood plywood panels use transparent or clear finishes that enhance the real wood surface, which is usually modified in color and appearance by stains, toners, fillers, sealers, glazes, and topcoats. Satisfactory finishes require a number of operations, which are shown in flow chart form in Figure 1-4.

The first step in finishing a hardwood panel is to fill the open knots with a putty material. The second step is to cut a groove and paint it with an opaque finish. The panel is then sanded prior to application of a stain, which gives the surface a uniform color without raising the grain of the wood fiber. The stain is normally applied by a direct roll coater with a grooved or wire-wrapped doctor roll to increase the application

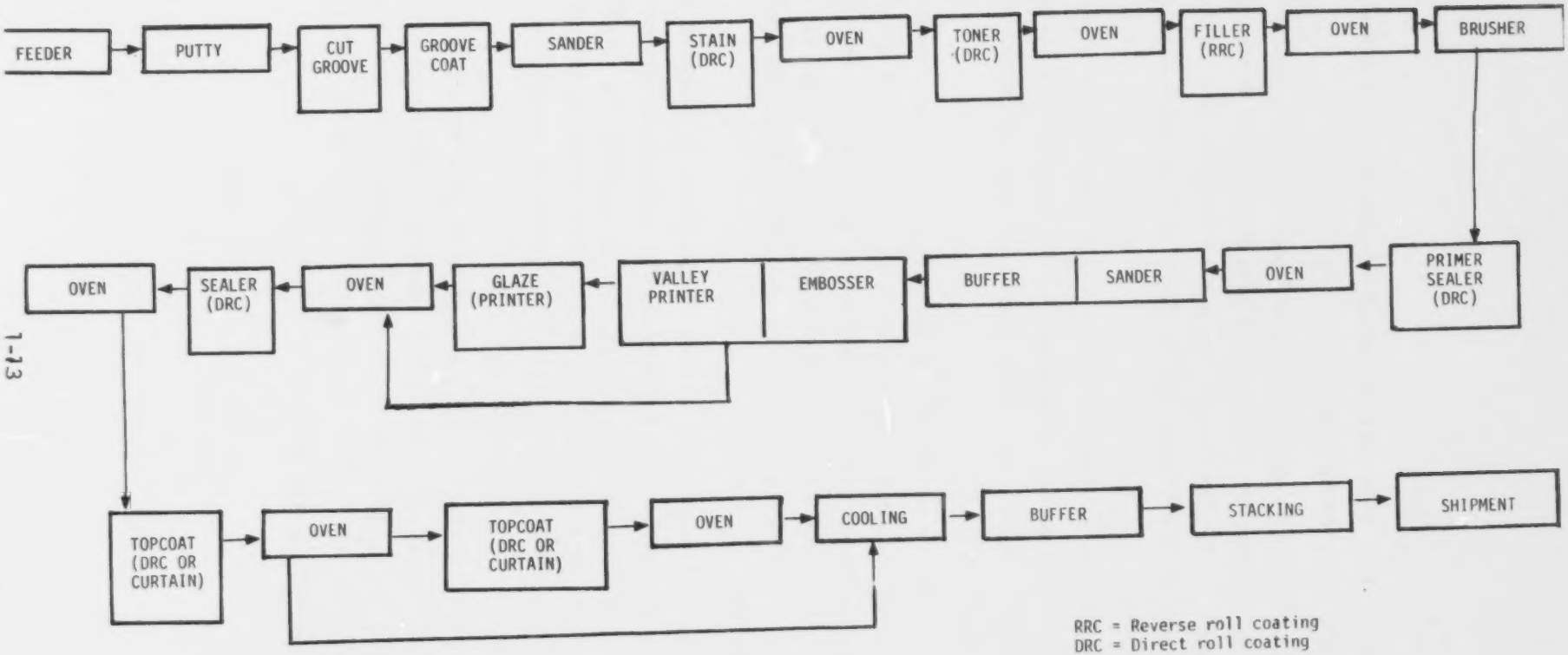


Figure 1-4. Natural Hardwood Plywood Interior Paneling Line

amount of this thin coating, which is then dried in a high velocity or infrared oven.

A thin wash coat, known as a "toner" if it is colored with dyes or transparent pigments, is then direct roll coated over the stain. The toner seals the stain, improves the clarity and lightness of the finish, and performs various other preparatory functions.

Next, the plywood is filled, usually by a reverse roll coater followed by a series of pads or brushes to glaze the surface of the wood. The sealed, filled panels are then dried and polished in a brush unit.

The primer sealer is the next coating applied, normally by direct roll coating. The sealer floods the complete panel, including the grooves, in order to protect the wood from moisture, provide a smooth base for the topcoat, and give gloss to the grooves. Following application, the sealer is dried, sanded, and buffed.

At this point, the surface of the panel is embossed and valley printed to give a distressed or antique appearance. One or more print steps may then be used to upgrade the veneer surface or provide special effects. This glaze is then dried and a sealer applied with a direct roll coater to smooth the surface in preparation for topcoating.

One or more topcoats are used to provide durability, protection, and gloss. Direct roll coating is the usual application method, but curtain coating may also be employed. The set topcoat is cured at 200 to 230^{o}F (93 to 110^{o}C). The panels are then cooled, buffed, and stacked for shipment.

1.4 SOURCES AND TYPES OF EMISSIONS

Emissions of volatile organic solvents at flat wood coating plants occur primarily at the coating lines. Solvents used in organic-based coatings are normally multicomponent mixtures that may include methyl ethyl ketone, methyl isobutyl ketone, toluene, xylene, butyl acetates, propanol, ethanol, butanol, VM&P naptha, methanol, amyl acetate, mineral spirits, SoCal I and II, glycols, and glycol ethers. Organic solvents most often used in water-borne coatings are glycol, glycol-ethers such as butyl cellosolve, propanol, and butanol. Ranges of nonvolatile materials and volatile organics present in the different types of conventional and water-borne coatings supplied to the flat wood coating industry are shown in Table 1-2. Information from PPG Industries and Reliance Universal indicates that there are no volatile organic compounds (VOC) in the newer water-borne fillers. Vaporization of organics at coaters and paint mixing and storage areas occurs at ambient temperature and pressure. Emissions from ovens are at ambient pressure and at temperatures determined by the substrate and the coatings used.

The primary fuel used in flat wood coating is natural gas; liquified petroleum gas is the primary backup fuel during curtailments of natural gas supplies or where natural gas is not available. Some coating plants employ infrared and/or ultraviolet cure ovens, which are electrically heated. This type of oven can normally eliminate onsite combustion emissions, such as carbon monoxide, unburned fuel, and nitrogen oxides.

Table 1-2. FLAT WOOD COATINGS[a]

Paint Category	Paint Type[b]	Number of Companies	Density (kg/liter)	Density (lb/gal)	Weight Percent: Non-Volatile	Weight Percent: Volatile Organics
Filler	C	4	1.7	14.5	70 - 85	15 - 30
	W	7	1.7	14.5	60 - 90	≈0[c] - 5
Sealer	C	3	1.1	9	50 - 85	15 - 50
	W	4	1.1	9	35 - 80	≈0[d] - 15
Basecoat	C	7	1.4	11.5	25 - 60	40 - 75
	W	7	1.4	12	35 - 80	< 2 - 7
Grain ink	C	6	1.2	10	30 - 70	30 - 70
	W	6	1.3	10.5	30 - 70	1 - 12
Topcoat	C	8	1.1	8.8	25 - 50	50 - 75
	W	9	1.1	9	25 - 60	1 - 15

[a] Source: Miscellaneous paint companies (including Inmont, Napko, PPG, Reliance Universal, and Sherwin-Williams) and Mr. Martin Kay, South Coast Air Quality Management District, California

[b] C = conventional; W = water-borne

[c] Reliance Universal and PPG Industries

[d] PPG Industries

References for Section 1.0

1. "Directory of Panel Plants-U.S.A.," Forest Industries, March 1976, pp. 122-125

2. National Particleboard Association, Directory of Particleboard and Medium Density Fiberboard Manufacturers, Silver Spring, Md., December 1975

3. American Plywood Association, "Plywood Paneling and Siding Manufacturers," Tacoma, Wash., no date

4. Acoustical and Board Products Association, "Insulation Board and Hardboard Plants in the United States," Park Ridge, Ill., March 1976

5. Hardwood Plywood Manufacturers Association, Where to Buy Hardwood Plywood and Veneer, Arlington, Va., August 1976

6. Wood and Wood Products/Reference Data Buying Guide, March 1977, pp. 9 and 10

7. Hardwood Plywood Manufacturers Association, Directory of Hardwood Plywood Prefinish Industry, Arlington, Va., May 1977

8. American Board Products Association, "Latest ABPA Listings of Hardboard Panel Converters," Park Ridge, Ill., April 1978

9. 1972 Census of Manufacturers, United States Bureau of Census, Vol. II, Industry Statistics, Part I. SIC 20-26, 2431, 2435, 2436, 2492, 24996

10. U.S. Environmental Protection Agency, "Recommended Policy on Control of Volatile Organic Compounds," Federal Register, Vol. 42, No. 131, 3T314-3T316, July 1977

2.0 APPLICABLE SYSTEMS OF EMISSION REDUCTION

Potential emission reduction systems are categorized as add-on devices, materials changes, and process changes. Add-on devices include incineration and adsorption systems, coupled with their attendant systems to capture the volatile organic compounds (VOC) being released at the affected facilities. Materials change refers to modifying a coating formulation so that the quantity of organic solvents per unit of solids is substantially reduced. Process modifications may be required, but are not the primary consideration involved in the change. Process changes include ultraviolet (UV) and electron beam (EB) systems, for which the physics of curing requires that specialized coating materials be used. Coating materials have been developed to take advantage of these curing processes.

2.1 ADD-ON DEVICES

2.1.1 INCINERATION

Afterburners have been used successfully for many operations with emissions similar to those from flat wood coating. The minimum control efficiency of an afterburner should be in excess of 90 percent of the vapors captured. Nineteen test reports of direct flame afterburners showed an average reduction efficiency of 95-percent across the afterburner, and eight tests of catalytic afterburners averaged 89-percent efficiency.[1,2] Overall plant control would be less because not all organic emissions are captured. Refer to Volume I, Section 3.2.2 for further discussion of incinerators.[3]

Of the more than 150 flat wood handling plants contacted, only two, both in southern California, have afterburners as add-on controls. Representatives of two equipment manufacturers who

were contacted had no knowledge of afterburners being installed as add-ons at other flat wood coating operations.[4,5] Nevertheless, the use of afterburners is a viable option for reducing VOC emissions where other control techniques are not applicable due to product requirements.

2.1.2 ADSORPTION

No adsorption system was found to be used in the flat wood industry. Multicomponent solvents and the use of different coating formulations for the several steps along the coating line are not conducive to the general use of adsorption to control flat wood coating emissions. Specific applications may be found, however, e.g., in redwood surface treatment, where over 90 percent of the coating is volatile and can be recycled. In this treatment, a solution of pentachlorophenol in mineral spirits is applied to redwood or cedar sidings for protection against mildew and water staining. This volatile solvent is recoverable and reusable with minimal processing. Further details on carbon adsorption are given in Volume I, Section 3.2.1.[3]

2.2 MATERIALS CHANGES

2.2.1 WATER-BORNE COATINGS

The use of water-borne coatings is continually increasing in the surface coating of flat woods, primarily for the reduction of VOC emissions. This material change can also result in reduced fire hazard, some reduction in fire insurance, improved working conditions, and reduced air pollution.

Paint manufacturers have developed and are continuing to develop water-borne coating formulations to replace conventional organic solvent-borne coatings for many factory flat wood applications. In water-borne coatings, the organic content of the volatile portion of the coating is normally 20 volume percent

or less. Typically, the use of an applicable water-borne coating in place of a conventional organic solvent-borne coating can reduce volatile organic emissions by at least 70 percent.

Values of volatile organics in water-borne and conventional coatings for factory application to flat woods are given in Table 2-1. From the range of VOC values provided by various paint manufacturers for their water-borne coatings, a fixed value was estimated for each paint category. The paint manufacturers contacted indicated that coatings with these estimated VOC contents are available, but not all paint manufacturers supply all of the listed coatings. Table 2-2 presents estimated VOC emissions for coating printed panels for interior use, assuming that the coatings listed in Table 2-1 are employed. For this example, complete conversion to available water-borne coatings would reduce VOC emissions by 84 percent.

Printed paneling for interior walls can be made of hardboard, particleboard and other composition boards, and lauan-faced plywoods. Also, the coating lines can differ substantially even when the same substrate is used. Thus, many lines can either apply fewer coatings or additional print inks and groove coats.

The major use of water-borne flat wood coatings is in the filler and basecoat applied to printed interior paneling. Limited use has been made of water-borne materials for inks, groove coats, and topcoats for printed paneling, and for inks and groove coats for natural hardwood panels.

Problems with water-borne coatings include grain raising, wood swelling, poor finish quality, difficulties in curing topcoats, and possible care required to prevent freezing. Volume I, Section 3.3.1 may be consulted for additional information concerning water-borne coatings.[3]

Table 2-1. VOLATILE ORGANICS IN FLAT WOOD COATINGS[a]

Paint Category	Paint[b] Type	Density (lb/gal)	Weight Percent Non-Volatile	lb VOC / gal	Typical VOC Content[c] (kg/liter)	Typical VOC Content[c] (lb/gal)	VOC Content Less Water (kg/liter)	VOC Content Less Water (lb/gal)	VOC Reduction for Equivalent Coverage (Percent)
Filler	C	14.5	75	2.2 - 4.4	0.43	3.6	0.43	3.6	-
	W	14.5	75	0 - 0.6	0.05	0.4	0.07	0.6	90
Sealer	C	9	60	1.4 - 4.5	0.43	3.6	0.43	3.2	-
	W	9	55	0 - 1.3	0.12	1.0	0.23	1.9	70
Basecoat	C	11.5	45	3.7 - 8.6	0.76	6.3	0.76	6.3	-
	W	12	55	0.1 - 0.8	0.08	0.7	0.19	1.6	90
Ink	C	10	40	3.0 - 7.0	0.72	6.0	0.72	6.0	-
	W	10.5	50	0.1 - 1.5	0.18	1.5	0.38	3.2	80
Topcoat	C	8.8	40	4.4 - 6.6	0.64	5.3	0.64	5.3	-
	W	9	45	0.1 - 1.4	0.17	1.4	0.32	2.7	80

[a] Data provided by Glidden, Inmont, Napko, Reliance Universal, Sherwin-Williams, etc. did not specify substrate; composition ranges were generally provided.

[b] C = conventional paint with organic solvent
W = water-borne, i.e., at least 80 percent of the volatile portion of the coating is water.

[c] Data received indicate that all companies providing information were able to meet the VOC content given for water-borne coatings.

Table 2-2. SAMPLE ESTIMATION OF VOC EMISSIONS FOR INTERIOR PRINTED PANELS[a]

Paint	Coverage[b] (gal/1,000 ft^2)		Potential VOC Emissions (lb/1,000 ft^2 coated)			Potential VOC Emissions (kg/100 m^2 coated)		
	Water-borne	Conventional Paint	Water-borne	Conventional Paint	Ultraviolet[c]	Water-borne	Conventional Paint	Ultraviolet[c]
Filler	1.6	1.7	0.6	6.1	nil	0.3	3.0	nil
Sealer	0.35	0.3	0.4	1.1	0	0.2	0.54	0
Basecoat	0.65	0.8	0.5	5.0	0.5	0.2	2.4	0.24
Ink	0.1	0.1	0.2	0.6	0.2	0.1	0.3	0.10
Topcoat	0.65	0.7	0.9	3.7	nil	0.4	1.8	nil
Total	3.4	3.6	2.6	16.5	0.8	1.2	8.0	0.4

[a] For included coating operations. Refer to Table 2-1 for VOC contents of coatings.

[b] Paint coverage based on information from Reference 6. Adjustments between water and conventional paints were made using typical nonvolatiles content.

[c] UV line uses no sealer, uses water-borne basecoat and ink. Total is adjusted to cover potential emissions from the UV coatings.

2.2.2 HIGH SOLIDS COATINGS

High solids coatings have shown promise for use on specific products other than wood. Although it has been demonstrated that high solids coatings can fill pores and seal wood, thus offering considerable encouragement, they do not appear practicable for current or near future use in the flat wood coating industry.[7] For additional information on high solids coatings, refer to Volume I, Section 3.3.2.[3]

2.3 PROCESS CHANGES

2.3.1 ULTRAVIOLET CURING

Ultraviolet curing is the most widely used process change and, where applicable, effects almost 100-percent reduction of VOC emissions. In the flat wood industry, UV systems have been found to be especially useful on particleboard coating lines and in specialty coating operations.

Ultraviolet curing is extremely fast: for a typical sealer/filler, an exposure of approximatley 10 seconds is sufficient. Thus, a 10 to 20 ft (3 to 6 m) UV oven can replace a 90 to 100 ft (30 m) thermal oven required for conventional paint.[8,9] Ultraviolet-curable coatings are a combination of resin, prepolymers and monomers, and photosensitizer (which serves as a catalyst). Polyester, acrylics, methane, and alkyds are common coating materials. Applied as a liquid, the coating is cross-linked and hardened on exposure to UV.

Although there have been attempts to develop opaque UV coatings, such coatings are not available.[10] Thus, in the flat wood industry, UV has found use only in the application of clear to semitransparent filler and topcoat for interior printed paneling and cabinetry products. Advantages are good machinability, extremely high solids,

low shrinkage, good adhesion to most substrates, good sanding qualities, and good chemical resistance.

One of the major disadvantages of UV coating systems is the limited number of available materials that can be successfully used to overcoat UV-cured paints. Intercoat adhesion of UV materials to water-borne and conventional solvent systems remains a problem. Other disadvantages include the hazards of potential exposure to UV radiation, ozone, and organic monomers, all of which may pose serious health problems.

2.3.2 ELECTRON BEAM CURING

One commercial facility in the United States uses an EB curing system. Opaque coatings can be cured to a depth of approximately 15 mils by this method; 3 to 5 mils of EB-cured coating produce a smooth, wear resistant finish with a performance comparable to many plastic laminates.[11,12] Costs of both the installed system (over $500,000) and the coating ($22 to $28 per gallon) limit the applicability of EB curing as a control technique. However, over 99 percent control of VOC can be expected. Monomers and ozone are possible emissions and some air-borne acrylics have been experienced.[11]

2.4 CONTROL LEVELS

For purposes of recommending levels of control, flat wood interior panel products have been divided into three subcategories: 1) printed interior wall panels made of hardwood plywood (principally lauan) and particleboard ; 2) natural finish hardwood plywood panels; and 3) Class I finishes for hardboard paneling. [Class I hardboard panels (principally exterior siding and tileboard), particleboard used in furniture, insulation board, and softwood plywood are not considered in this document.] Recommended VOC limitations are given in kg/100 m^2 (lbs/1000 ft^2) of surface covered to allow panel coaters maximum flexibility in adjusting VOC content of the different coatings so as to meet the emission limitation while maintaining product quality.

2.4.1 PRINTED INTERIOR WALL PANELS MADE OF HARDWOOD PLYWOOD AND PARTICLE-BOARD

Finishing of panels in this category is characterized by the use of fillers and basecoats which obscure the grain or natural surface. Simulated grain patterns or other decorative patterns are then printed on the surface. The recommended VOC limitation of 2.9 kg/100 m^2 6.0 lbs/1000 ft^2 of surface coated permits the use of conventional organic solvent-borne coatings for topcoats and inks, but will require use of water-borne coatings for some of the coating types.

The composition of the different coatings used on a given panel will vary, but the recommended limitation is equivalent to an average coating with a VOC content of 0.20 kg/l (1.7 lbs/gal).* Few, if any, coatings will have this composition. Water-borne coatings will have less VOC and the solvent-borne coatings more VOC, but the total VOC of all the coatings used must meet the limitations. In terms of limitations used in previous documents. the recommended limitation is equivalent to an average coating with a VOC content of 0.29 kg/l (2.5 lbs/gal) less water.*

The recommended emission limit will provide an emission reudction of about 70 percent compared to the use of conventional coatings. This assumes conventional coatings have an emission rate of 18.2 lbs/1000 ft^2, which is derived from the total of 16.1 in Table 2-2 by subtracting 1.1 lb/1000 ft^2 for sealer (because this product does not require a sealer) and adding an additional 3.2 lb/1000 ft^2 to allow for coating the grooves. This modification results in a more representative total figure for printed hardwood plywood.[13]

2.4.2 NATURAL FINISH HARDWOOD PLYWOOD

Finishes in this cateogry are characterized by use of essentially transparent coatings frequently supplemented by fillers, toners and other preliminary coats that complement the natural grain of the wood and maintains its intrinsic attractiveness.

*Calculations in Appendix B-II

A recommended VOC limitation of 5.8 kg/100 m^2 (12.0 lb/1000 ft^2) of surface coated permits the use of conventional organic coating solvents for most applications, but with somewhat decreased amounts of VOC. Water-borne groove coats and some water-based inks are being used commercially; however, product qualitycannot be maintained by use of the other developmental water-borne coatings. The recommended emission limit is equivalent to the usage of coatings which average 0.40 kg/l (3.3 lbs/gal) of VOC. This is equivalent to the usage of organic solvent-borne coatings average 55 percent solids*

A typical total emission rate for coating panels with natural finish coatings is 24 lbs/1000 ft^2.[13] Thus, the recommended emission limits will result in a 50 percent reduction in emissions of VOC for this category.

2.4.3 CLASS II FINISHES FOR HARDBOARD PANELS

Factory applied finishes for hardboard panels are classified as Class I and Class II by American National Standards Institute under Voluntary Product Standard PS 59-73. Class II finish has no heat, humidity, or steam resistance requirements as it is not meant to be used where these conditions are excessive. Combinations of water-borne and solvent-borne coatings can be used to meet the recommended emission limit and produce a panel which meets the Class II requirements.

The recommended emission limit of 4.8 kg/100 m^2 (10 lbs/1000 ft^2) is equivalent to the usage of coatings which average 0.34 kg/l (2.8 lbs/gal) of VOC. Assuming 40 percent solids, this would be equivalent to 0.43 kg/l (3.6 lbs/gal) less water.*

*Calculations in Appendix B-II

References for Section 2.0

1. Test Report Summaries, Los Angeles County Zone, South Coast Air Quality Management District (SCAQMD), El Monte, Calif.

2. Gadomski, R.R. et al., Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase II, Graphic Arts Technical Institute, Pittsburgh, Pa. 1973

3. U.S. Environmental Protection Agency, Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations, EPA-450/2-76-028 (OAQPS No. 1.2-067), Research Triangle Park, N.C., November 1976

4. Harr, G.R., Hirt Combustion Engineering, Montebello, Calif.

5. William, P., Ashdee Division of George Koch Sons, Inc., Evansville, Ind., September 1977

6. Russel, P., Abitibi Corporation, Cucamonga, Calif.

7. Price., M.D., Reliance Universal, Inc., "The Future of High-Solids Coatings," Proceedings of the Fourth Water-Borne and Higher-Solids Coatings Symposium, New Orleans, La., 1977, p. 155

8. Koch, R.L., Ashdee Division of George Koch Sons, Inc., "UV-Curing of Particleboard," Bulletin, Evansville, Ind.

9. PPG Industries, "A Cure for Energy, Pollution and Plant Space Woes," PPG Products, Vol. 184, No. 2, Pittsburgh, Pa., 1976

10. Leary, P.E., Reliance Universal,Inc., "Ultraviolet Curable Coatings for Industrial Finishings," American Paint and Coatings Journal, Vol. 59, No. 15, 1974, pp. 86, 88, 90, 92

11. Christopherson, B., and Carnagey, D., Brookes-Willamette Corporation, Bend, Ore.

12. "Space-Age Coating of Particleboard Offers Durable Surface," Furniture Methods and Materials, May 1977

13. Letter of comment to EPA from Hardwood Plywood Manufacturers Association, Arlington, Virginia. May 17, 1978.

3.0 COSTS AND ANALYSES OF CONTROL OPTIONS

3.1 INTRODUCTION

3.1.1 PURPOSE

The purpose of this section is to present estimated costs and cost analyses for the control of volatile organic compound (VOC) emissions from existing flat wood interior panel coating lines.

3.1.2 SCOPE

Estimates of capital and annualized costs are presented for controlling VOC emissions from a model printed interior panels coating line that includes the application and curing of filler/sealer, basecoat, ink, and topcoat. Two categories of VOC control techniques, changes in coating material to water-borne and ultraviolet (UV) coating systems, have been costed. The alternatives considered include (1) the complete conversion -- except ink -- to a water-borne system, and (2) use of UV-curable coatings for the filler and topcoat, with a water-borne basecoat.

Control devices such as afterburners and adsorbers are not generally suitable as retrofit emission control systems for existing interior wall panel coating plants. Cost information for incineration and adsorption systems will not be discussed herein, but general information can be obtained from Volume 1, Section 4.2.2.[1] Note, however, that add-on devices are viable control techniques for VOC and are not ruled out on the basis of emission limits or applicability.

3.1.3 USE OF MODEL PLANTS

For the interior wood panel coating industry, facility size is normally a function of the number of finishing lines. It is assumed

that differences in modifications of the various finishing lines for the same process change are not significant. Therefore, costs are estimated for typical modifications required to one line, and several throughputs for the one line are then considered. The basis for the throughputs is the number of hours of operation, since the production rate of a given line is essentially constant. Also, existing plants are assumed to use conventional organic solvent-based coatings for all applications.

For both control systems analyzed, water-borne and UV coatings, three throughputs were considered: coating of 1,000,000, 1,920,000, and 4,000,000 standard panels per year. A standard panel is 32 ft^2 (2.97 m^2). Prior studies had used 1,920,000 panels per year for a one shift operation as a basis for evaluation.[2] This rate of production was used as a midpoint in the present analysis; those who do not coat daily are represented by the lower production value, and the higher value represents two full shifts of operation per day.

Model plant control cost estimates will differ from actual costs. This is especially true for the coating of interior wall panels because different substrates are used, different finishes are applied (due to process and customer requirements), and there are plant-to-plant process differences, such as existing line equipment and line speed. Model plant estimates are, however, the most convenient means of comparing the relative costs of alternative control measures.

3.1.4 BASES FOR ESTIMATES OF CAPITAL COSTS

Capital cost represents the total investment required for the purchase and installation of each control option. Costs due to production losses during installation and startup, retraining of personnel, and other items affecting production are not included.

Major equipment purchases are not normally necessary to convert from conventional to water-borne coatings. However, costs can be

incurred (1) to shield or substitute corrosion resistant material for those components that come into contact with and can be affected by the coating, and (2) to provide a higher oven temperature or to increase oven length. For facilities that do not utilize forced airflow over the coatings, additional heating capacity and blowers may be required. In most facilities, forced airflow exists to minimize organic solvent concentrations in the work area and to maintain the organic content in oven exhaust at low levels. For such coaters, a net reduction in energy requirements may result.

Use of UV systems is limited to the application of filler and topcoat to the wood. Ultraviolet curing systems require a significant capital investment. If conversion to water-borne coatings is also desired, further expenditure is necessary.

3.1.5 BASES FOR ANNUALIZED COST ESTIMATES

Annualized cost estimates consist of the differences in expenditures between controlled and uncontrolled processes for direct operating costs and annualized capital charges. A summary of factors used in computing the annualized costs appears in Table 3-1.

Direct operating costs include expenditures for the following items:

- Labor
- Materials (including solvent)
- Utilities
- Disposal of wastes

Annualized capital charges include the following expenses:

- Depreciation and interest
- Taxes, insurance, and administration

The depreciation and interest is computed by multiplying the capital cost by a capital recovery factor, which is dependent on the life of

the equipment at an appropriate interest rate. The taxes, insurance, and administration are determined by multiplying the capital cost by a factor of 4 percent.

3.2 CONTROL OF SOLVENT EMISSIONS

Developing estimates for the control of VOC emissions from the coating of flat woods is not a straightforward task. In addition to a wide diversity in the types and needs of existing facilities, the procedures used to establish similar control systems are also varied. This results in a lack of models that exemplify what might be called a "standard" system. Also, facilities tend to make use of equipment they already have and are often able to improvise. Moreover, it was found that there were significant plant-to-plant differences in applying the same emission control techniques, and that not every plant controlled emissions from the same coating function. Therefore, the following presentation is based on the experiences of those who have installed various segments of a control system. Using these data, costs for installation of complete systems are estimated.

3.2.1 RETROFIT COSTS OF WATER-BORNE SYSTEMS

The coaters who provided data indicated that the total cost for conversion system procurement and installation ranged from $40,000 to $55,000. Costs were accumulated on the basis of the processes employed in a water-borne system (filler/sealer, basecoat, and topcoat). For each process, equipment modifications cost $5,000 to $7,000, installation and startup expenses ranged from $7,000 to $10,000, and system engineering and design work was between $1,000 and $2,000.[4] Thus the cost of an individual process was between $13,000 and $19,000.

3.2.2 OPERATION OF A WATER-BORNE SYSTEM

Operation of a water-borne system should result in little change in labor and energy costs. Labor requirements are identical with those necessary for a solvent-based system. Energy needs should grow as a result of increased temperature and airflow requirements in the ovens. However, this increase will be compensated for by a decrease in the blower requirements needed to maintain safe working areas and to insure that organic concentrations in exhaust do not exceed approved limits.

The major element affecting cost in the changeover to a water-borne system is the cost differential of materials, especially the cost of paint. Estimates of paint costs, assuming a facility with a complete coating system and based on factors shown in Table 2-2, are given in Table 3-1.

3.2.3 RETROFIT COSTS OF ULTRAVIOLET/WATER-BORNE SYSTEMS

Since UV systems cannot be used to apply a basecoat, a water-borne process must be used. From the previous discussion, this cost can be estimated at $15,000.

For the filler/sealer and topcoat processes, equipment expenses should run between $45,000 and $55,000 per process, including the purchase of an oven and other items. Installation and startup costs vary from $10,000 to $15,000, and engineering and design costs $3,000 to $5,000 per process. Summing up these estimates yields a price tag of $130,000 to $165,000 for retrofitting a UV/water-borne system.[4-7]

3.2.4 OPERATION OF AN ULTRAVIOLET/WATER-BORNE SYSTEM

Labor costs should not change due to conversion to a UV/water-borne system, but energy costs will decrease. The power requirements

Table 3-1. COST FACTORS USED FOR COMPUTING ANNUALIZED COSTS

I. Direct Operating Costs

1. Materials[a,b]

	Cost per 1,000 ft^2 (100 m^2) Covered					
	Organic		Water		Ultraviolet	
Filler	$ 6.00	($ 6.50)	$ 6.40	($ 6.90)	$ 9.00	($ 9.70)
Sealer	0.90	(1.00)	1.05	(1.10)	-	(-)
Basecoat	4.00	(4.30)	3.60	(3.90)	3.60	(3.90)
Ink	1.30	(1.40)	1.35	(1.45)	1.35	(1.45)
Topcoat	3.20	(3.40)	4.55	(4.90)	3.30	(3.55)
Total	$15.40	($16.60)	$16.95	($18.25)	$17.25	($18.60)
Lamps[c]					$150 each	

2. Utilities

Electricity (net savings)[d]	$0.50 kW at 130 kW/hr

II. Annualized Capital Charges

1. Depreciation and interest expense	13% of capital cost
2. Taxes, insurance, and administration	4% of capital cost

[a] Refer to Table 2-2 for coverage factors.

[b] Paint costs per gallon:

	Paint Costs Per Gallon		
	Organic	Water	Ultraviolet
Filler	$ 3.50	$ 4.00	$ 8.00
Sealer	3.00	3.00	-
Basecoat	5.00	5.50	-
Ink	12.50	13.50	-
Topcoat	4.50	7.00	10.00

[c] From Reference 3.

[d] From Reference 2.

for UV lamps are 10 kilowatts per 50-inch lamp, so for two 12-lamp systems replacing infrared ovens, a reduction of 130 kilowatts per shift hour will be realized.[2] Reduced blower needs will also add a minimal amount to the energy savings.

As with the water-borne system previously discussed, material costs, such as paint expenses and lamp replacement, will have a major impact. Paint costs are listed in Table 3-1. A sealer is not required with the UV filler and the basecoat is water-borne. Therefore, the increased cost for coatings that are UV-cured is approximately \$1.80 per 1,000 ft^2 (\$1.95 per 100 m^2). Ultraviolet lamps have a normal burn life of 2,000 to 8,000 hours, depending on their use. Therefore, they should be replaced every 1 to 4 years. At a cost of \$150 per lamp, a complete set of 24 costs \$3,600.[3]

3.2.5 NET ANNUALIZED COST

Net annualized cost estimates for water-borne and UV/water-borne systems are given in Table 3-2. This table compares the net annual cost of the two methods for three different throughput levels. In gathering the cost data, a range was noted for almost all expenses, so an effort was made to use the values that are most likely to reflect the expected costs. The footnotes provide explanatory information as to how this table was compiled.

3.3 COST-EFFECTIVENESS ANALYSIS

The cost-effectiveness analysis was conducted by first describing the incremental annual costs required for existing facilities to institute a program of effective VOC control. These costs were then compared with the expected VOC reductions in order to determine cost-effectiveness over the useful life of the system.

The analyses were based on the following principles:

- The discount rate (cost of capital) was taken to be 10 percent.
- The useful life of each system was taken at 15 years, with no salvage value.
- A capital recovery factor was used to allocate the cost of equipment and interest over its useful life.
- Insurance, taxes, and administrative expenses were taken as a standard percentage of capital expenditures.

The results of the cost-effective analysis are listed in Table 3-2, and are graphically presented in Figure 3-1. These results clearly show that the water-borne method is more cost-effective, and illustrate the impact of throughput on each method. Throughput has a much smaller effect on the water-borne method than it does on its UV/water-borne counterpart. While the total variation in the former case is just 3 cents per kilogram of hydrocarbon controlled, the difference is 9 cents in the latter case. The use of lower VOC content water-borne coatings (10 to 15 percent of the volatile portion) would further reduce emissions and improve cost-effectiveness.

Table 3-2. NET ANNUALIZED COST ESTIMATES

Shifts	Less Than 1		1		2	
Panels	1,000,000		1,920,000		4,000,000	
Feet^c/Year	32,000,000		61,440,000		128,000,000	
	Water-Borne	Ultraviolet/ Water-Borne	Water-Borne	Ultraviolet/ Water-Borne	Water-Borne	Ultraviolet/ Water-Borne
Installed capital cost[a]	$ 52,000	$155,000	$ 52,000	$155,000	$ 52,000	$ 155,000
Direct operating cost						
Paint[b]	48,000	57,600	92,200	110,600	192,000	230,400
Lamps[c]		1,800		1,800		3,600
Utilities[d]		(6,500)		(12,480)		(26,000)
Capital charges	8,840	26,350	8,840	26,350	8,840	26,350
Net annualized cost	$156,000	$ 79,200	$101,000	$124,600	$ 200,800	$ 234,400
Controlled emissions (kg)	196,000	222,100	376,000	426,000	783,800	888,100
Controlled emissions (lb)	432,000	489,600	829,000	940,000	1,728,000	1,958,000
Cost-effectiveness ($/kg)	0.286	0.357	0.269	0.292	0.256	0.264
Cost-effectiveness ($/lb)	0.130	0.162	0.122	0.132	0.116	0.120

[a] Installed capital cost for water-borne method

Installation and startup costs	$ 30,000[4]
Increase in oven capacity	10,000[4]
Pumps ($1,000 per process)	3,000[4]
Engineering and development cost	3,000[4]
Blowers (4 per process at $500 each)	6,000[4]
Total	$ 52,000

Installed capital cost for ultraviolet/water-borne method

Installation and startup costs (filler and topcoat)	$ 24,000[4,7]
Ovens (2 at $45,000)	90,000[3,5-7]
Add-on equipment (for filler and topcoat)	16,000[4]
Engineering and development cost	9,000[4] est.
Water-borne for basecoat	16,000[4]
Total	$155,000

[b] Water-borne $1.50/1,000 ft^2 x throughput

Ultraviolet/water-borne $1.80/1,000 ft^2 x throughput

[c] $150 per lamp. Useful life assumed to be 2 years for one shift or less, and 1 year for two shifts.[3]

[d] $0.50 per KW x 130 KW per hour x annual hours of operation.

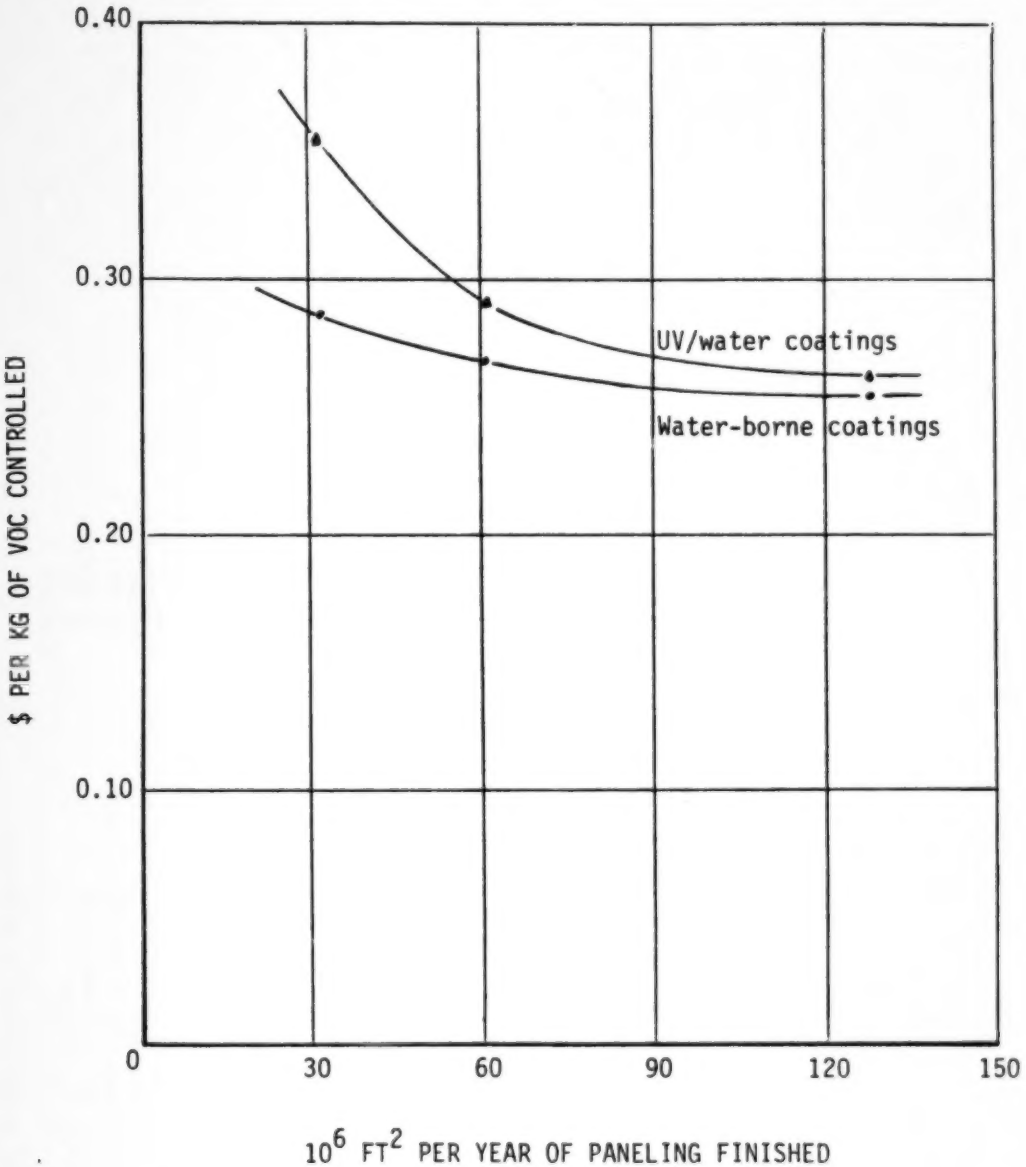


Figure 3-1. Cost Effectiveness for VOC Control at Existing Printed Panel Coating Plants

References for Section 3.0

1. U. S. Environmental Protection Agency, Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations, EPA-450/2-76-028 (OAQPS No. 1.2-067), November 1976
2. Springborn Laboratories, Inc. (formerly Debell and Richardson), "Air Pollution Control Engineering and Cost Study of Surface Coating Industries," First Interim Report, Appendix, Basis for Coatings, Case B-2, Prepared for U.S. Environmental Protection Agency, 1976
3. Martin, M., PPG Industries, Inc., Plainfield, Ill.
4. Springborn Laboratories, Inc. (formerly Debell and Richardson), Report of trips made to plants during December 1975 through March 1976
5. Christopherson, B., Brooks-Willamette Corporation, Bend, Ore., 1977.
6. Nickolson, T., Ashdee-George Koch, Inc., Evansville, Ind., 1977.
7. Estipia, J., General Wood Corporation, Buena Park, Calif., 1977.

4.0 EFFECTS OF ACHIEVING EMISSION LEVELS REPRESENTATIVE OF RACT

Although there are no known coating systems (filler, sealer, basecoat, groove coat, printing inks, topcoat) available that utilize all water-borne coating, the emission levels recommended in Section 2.4 can be met by a combination of water-borne, conventional solvent-borne, and higher solids coatings.

If the recommended limits are adopted, it is estimated that the overall reduction in VOC from manufacture of the three types of products would decrease by about 60 percent.* Furthermore, since these three categories account for an estimated 85 percent of the coatings consumed by all flat wood products, the overall emission reduction from the entire flat wood industry would amount to about 50 percent.

4.1 WATER-BORNE SYSTEMS

The beneficial aspects of using water-borne coatings include reduced toxicity, reduced VOC emissions, reduced fire hazard (which results in lowered insurance rates), and no add-on control requirements. In addition, costs are generally lower than those required for other applicable emission control technology.

Although water-borne materials are safe to handle and easy to clean up, equipment must be cleaned while wet. If water-borne coatings are allowed to dry on the applicator, the dried material will flake off and affect the quality of the product. Interruptions in operations therefore require that critical equipment be cleaned or kept wet.

For users of large quantities of coating, water treatment and disposal can also become a problem. In some instances, water is collected in drums and the paint is allowed to coagulate; the sludge is then separated and disposed of as solid waste. The waste water is normally disposed of through the sewage system. Some facilities use part of the wash water to coat back sides of panels at customer request.

*Appendix B-III details the rationale for this estimate.

4.2 ULTRAVIOLET - CURABLE COATINGS

The advantages of ultraviolet-curable coatings include reduced power requirements, very little emission of VOC, and the essentially 100 percent usable coating (since all components of the coating normally react and become part of the coating). As a result, blower requirements are negligible, space savings are effected by reduced storage and oven space needs, and very little waste is produced for disposal. Moreover, cure times can be measured in seconds and a superior product results. Since little or no curing takes place after the panel leaves the oven, proper cure times must be carefully established. Safety precautions must be taken to minimize exposure to UV radiation and to avoid contact with the coating as some of the raw materials can cause chemical burns.

5.0 MONITORING TECHNIQUES AND ENFORCEMENT ASPECTS

As indicated previously, add-on control devices are not generally applied to the factory prefinishing of flat woods. However, they may be used to meet VOC emission control requirements. Thus, regulations must not only specify that a given percentage of nonmethane VOC be either converted to carbon dioxide and water or be adsorbed, but must also require that approved capture systems be used in conjunction with the add-on devices. Since suitable techniques for testing capture systems are dependent on the facility, it is recommended that each facility be individually reviewed to assure that a satisfactory capture system is installed. Volume I, Section 5.0 of this series should be consulted for approaches to the determination of total nonmethane hydrocarbons.[1]

For facilities that control emissions by using coatings containing lower overall VOC, emission measurements to determine compliance may be difficult. Whether or not direct emission measurements can be correlated with the rate of finishing interior panels must be determined on an individual basis.

For most plants, emission estimates require knowing the VOC content of each coating, the quantity of each coating used per thousand square feet of each product finished, and any additional quantities of VOC used.

Density and volatile content of coatings can be determined by using ASTM D 1475-60, ASTM D 1644-59, and ASTM D 2369-73. Applicability, and procedures for using these methods to determine the volatile content of paint, varnish, lacquer, and related products are given in Volume II, Appendix A.[2] These methods are not applicable to coatings that require UV or EB curing. If an analysis of these special coatings is required, alternative methods must be developed. Procedures for calculating the quantity of VOC per volume of paint, given the composition and density of the coating, are presented in Appendix A.

If the pounds of VOC per gallon of coating and the spread rate of the coating (in square feet per gallon) are known, pounds of VOC per 1,000 ft^2 for each coating can be computed as shown in Appendix B. The sum of the pounds of VOC per 1,000 ft^2 for each coating applied to a specific product would give the final pounds of VOC per 1,000 ft^2. An alternative procedure would be to obtain, for each relevant facility, data on the quantity and VOC content of each type of coating used, the quantity of solvents used as diluent, and the amount of finished paneling produced during a specified period of time. These data permit computation of the average pounds of VOC per 1,000 ft^2 of product finished.

With the recommended system of emission limitations, enforcement becomes relatively difficult. For some regulating agencies, limitations in pounds of VOC per unit volume of coating may be more suitable. Field personnel can then collect samples, have them analyzed, and make determinations more rapidly.

Overall average values of VOC content for the recommended limits are estimated to be 0.20 kg/l (1.7 lb/gal) for printed hardwood panels, 0.40 kg/l (3.3 lb/gal) for natural finish panels, and 0.34 kg/l (2.8 lb/gal) for Class II hardboard panel finishes. Since each coating type differs in both composition and spread rate, these values cannot be applied indiscriminately to all coatings.

References for Section 5.0

1. U.S. Environmental Protection Agency, Control of Volatile Organic Emissions From Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations, EPA-450/2-76-028 (OAQPS No. 1.2-067), November 1976

2. U.S. Environmental Protection Agency, Control of Volatile Organic Emissions From Existing Stationary Sources - Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light Trucks, EPA-450/2-77-008 (OAQPS No. 1.2-073), May 1977

APPENDIX A

DETERMINATION OF VOC IN COATINGS

Data Required:

Coating density D (lb/gal)

Paint composition non-V, V, VOC, H_2O

where:

V = volatiles, including water

VOC = volatile organic compounds = 7.36 lb/gal (Vol II, p. D-2)

H_2O = water = 8.34 lb/gal

For Conventional Paint

(data in weight %): $VOC = \left[\frac{\% \text{ VOC}}{100}\right] (D)$ lb/gal

(data in volume %): $VOC = \left[\frac{\% \text{ VOC}}{100}\right] (7.36)$ lb/gal

For Water-Borne Paint

(data in weight %)

% of total coating: $VOC = \left[\frac{\% \text{ VOC}}{100}\right] (D)$ lb/gal

% of volatiles: $VOC = \left[\frac{\% \text{ VOC}}{100}\right] \left[\frac{\% \text{ V}}{100}\right] (D)$ lb/gal

(data in volume %)

% of total coating: $VOC = \left[\frac{\% \text{ VOC}}{100}\right] (7.36)$ lb/gal

% of volatiles: $VOC = \left[\frac{\% \text{ VOC}}{100}\right] \left[\frac{\% \text{ V}}{100}\right] (7.36)$ lb/gal

For VOC (lb/gal less water)

$$VOC = \frac{\left(\text{VOC lb/gal}\right)}{\left(1 - \frac{\text{Volume \% } H_2O}{100}\right)} \text{ lb/gal less water}$$

Conversion

lb/gal times 0.12 = kg/liter

APPENDIX B

CALCULATIONS OF EMISSION RATES AND REDUCTIONS

I. Weight of VOC Per 1,000 Square Feet of Finished Product*

1. In the determination of potential volatile organic compound (VOC) emissions from an interior wall paneling finishing plant, two important factors must be known:

   (1) lb VOC/gal -- This factor is known by the formulator of the industrial finish (the amount of solvent added can be obtained from the finisher, or samples of the coating can be tested).

   (2) Spread rate in ft^2/gallon -- This factor is known and/or can be calculated as it relates to each product finished by the hardwood plywood manufacturer.

The appropriate formula for determining lb VOC/1,000 ft^2 of a coating type is:

$$\text{lb VOC/1,000 ft}^2 = \frac{\text{lb VOC/gal} \times 1{,}000}{\text{Spread rate in ft}^2\text{/gal}}$$

Example:

lb VOC/gal of a coating = 4.20

Typical spread rate = 1,800 ft^2

$$\text{lb VOC/1,000 ft}^2 = \frac{4.20 \text{ lb/gal} \times 1{,}000}{1{,}800 \text{ ft}^2\text{/gal}}$$

$$\text{lb VOC/1,000 ft}^2 = 2.33$$

Note: A listing of coating types applied and their respective spread rates per gallon should be available from the hardwood plywood factory finisher. Spread rates can also be estimated by the formula given in Part B.

The lb VOC/1,000 ft^2 of each coating type applied can be added together to obtain lb VOC/1,000 ft^2 of finished product.

---

* Source: W.J. Groah, Hardwood Plywood Manufacturers Association, Arlington, Va.

2. The formula for approximating coating type spread rate is:

$$\text{Theoretical spread rate } (ft^2/gal) = \frac{1{,}604 \times E \times \text{Percent volume solids per gal}}{\text{Film thickness in mils}}$$

Where 1,604 = a constant based on the application of 1 gallon (0.1337 ft^3) material of 100 percent solids applied 1 mil (0.001 in) thick.

E = percent efficiency for application of finish. For roller coating applications (predominant in the interior panel finishing industry), E can be taken as 0.95 (i.e., 95 percent of material used is applied to the product).

Film thickness is measurable using various techniques.

II. Equivalency of Emission Rates per Area Coated vs. VOC Per Volume of Coating

1. Printed Hardwood Plywood Panels

Table 2.2 is assumed to apply to this category. A coverage rate of 3.5 gal/1,000 ft^2 is appropriate.

$$\text{Emission limitation equivalency} = \frac{6.0 \text{ lbs}/1{,}000 \text{ ft}^2}{3.5 \text{ gal}/1{,}000 \text{ ft}^2}$$

$$= 1.7 \text{ lbs/gal } (0.20 \text{ kg/l})$$

Assuming a typical coating has a solids content of 40 percent, and solvent density is 7.36 lbs/gal, the average coating composition would be: 40 percent solids, 23 percent organic solvent ($\frac{1.7}{7.36}$), and 33 percent water.

$$\text{Emission limit equivalence on a water-free basis} = \frac{1.7 \text{ lbs/gal}}{1 - 0.33} =$$

2.5 lbs/gal less water
(0.29 kg/l)

2. Natural Finish Hardwood Plywood Panels

A coverage rate of 3.6 gal/1,000 ft^2 is assumed.

Emission limitation equivalency =

$$\frac{12.0 \text{ lbs}/1{,}000 \text{ ft}^2}{3.6 \text{ gal}/1{,}000 \text{ ft}^2} = 3.3 \text{ lbs/gal (0.40 kg/l)}$$

If no water-borne coatings are used, this limitation would require the average coating to contain 45 percent solvent (3.3/ 7.36), and 55 percent solids. The water-free emission limit would be the same, 3.3 lbs/gal less water (0.40 kg/l less water).

3. Class II Finishes for Hardboard Panels.

A coverage rate of 3.5 gal/1,000 ft^2 is assumed.

Emission limitation equivalency =

$$\frac{10.0 \text{ lbs}/1{,}000 \text{ ft}^2}{3.5 \text{ gal}/1{,}000 \text{ ft}^2} = 2.8 \text{ lbs/gal (0.34 kg/l)}$$

Assuming a typical coating has a solids content of 40 percent, the average coating composition would be: 40 percent solids, 38 percent organic solvent(2.8/7.36) and 22 percent water.

Emission limit equivalency on a water-free basis =

$$\frac{2.8 \text{ lbs/gal}}{1 - 0.22} = 3.6 \text{ lbs/gal less water (0.43 kg/l)}$$

III. Emission Reductions Achievable by the Recommended Limitation

Compared to the use of conventional organic solvent-borne coatings with no emission controls, achievement of the recommended limits will result in reduced emissions in each category in the following ratios:

Printed Hardwood: 70 percent reduction
Natural Hardwood: 50 percent reduction
Class II Hardboard: 50 percent reduction

The relative production of the three categories on a nationwide basis is estimated to be as follows:

Printed Hardwood: 55 percent of total
Natural Hardwood: 15 percent of total
Class II Hardboard: 30 percent of total

If the recommended levels are adopted it is estimated that the emission reduction of each category as a percent of the total for the three

categories is as follows:

Printed Hardwood:	38 percent of total
Natural Hardwood:	7 percent of total
Class II Hardboard:	15 percent of total
Total reduction	60 percent

Production of the three categories is estimated to be 85 percent of the total of all factory finished flat wood products. The overall emission reduction will be about 50 percent of the total emissions from all flat wood products.

APPENDIX C

EFFECT OF DEPRECIATION AND TAXES

Tax incentives and depreciation may have a significant impact for many companies contemplating a vapor recovery investment. In this connection, the Internal Revenue Code includes special provisions for firms, and especially small businesses purchasing and installing certified pollution control facilities. In addition to all interest payments being deductible expenses for tax purposes, Section 169 of the Internal Revenue Code permits rapid write-off of such certified investments. Under this regulation a business may choose to depreciate its newly acquired equipment over a 60-month period instead of over its useful life. Employing the straight line depreciation method, 20 percent of the cost of this investment would be deductible annually for 5 years.

Sections 46 and 50 of the code deal with the subject of investment tax credits. All businesses may credit 10 percent of the cost of equipment with a depreciable life of at least 7 years to their actual tax liability. Lesser percentages may be credited for equipment depreciated over a minimum of 3 years to a maximum of 6 years; for a life of 3 or 4 years, the investment tax credit is 3.33 percent; for 5 or 6 years, the credit is 6.67 percent. The purpose of this regulation is to provide businesses with added incentives to purchase equipment.

Finally, Section 179 of the code furnishes small business with an additional opportunity to reduce their taxes. It permits an added first year bonus depreciation allowance equal to 20 percent of the purchase price of the equipment up to a maximum of $2,000. If this bonus depreciation is taken by the taxpayer, he must make an appropriate reduction in the basis of the equipment.

Accordingly, a small business may be able to deduct its interest expense plus up to 30 percent of the purchase and installation price

of certified pollution control equipment during the first year. Other businesses will be able to deduct up to 25 percent plus interest charges during the first year.

Let us examine the effect of these regulations on a particular pollution control expenditure. Suppose a facility was required to spend $10,000 for its equipment and installation, and $1,000 per year for operations and maintenance. What is the aftertax cost of this expenditure for both a regular business and a qualifying small business? Let us assume the marginal tax is 48 percent for a regular business and 22 percent for a small business and that the cost of capital is 10 percent. The appropriate calculations are shown in Table C-1.

Tax deductible expenses include depreciation, operations and maintenance costs, and property taxes. For a qualifying small business, there is also bonus first year depreciation. The total tax related savings is calculated by taking the sum of the present value of all deductible expenses, multiplying this figure by the marginal tax rate, and adding the investment tax credit. This figure is then subtracted from the before tax present value cost to determine the "true" expense. Interest payments have not been included in this example.

Property taxes are assumed to be paid at the end of each year, while operating and maintenance expenditures are assumed to be continuous throughout the year. Accordingly, the latter are attributed to the yearly midpoint for computing present values.

For a regular business, total present value expenses would be $10,000 + $1,536* + $6,443,** yielding $17,979. With a tax savings of $8,075, the true cost is $9,904. For a small business, the tax savings would be $4,096, generating a true cost of $13,883.

* Property taxes
** Operating and maintenance costs

Table C-1. COMPUTATION OF PRESENT VALUE TAX SAVINGS

Regular Business

Year	Depreciation		Property Taxes		Mid-Year Operations and Maintenance		PV Total Deductible Expense	Total Savings After Tax[a]	Investment Tax Credit at 6.67%		PV of Tax Savings at 7%
	F$[b]	PV[c]	F$	PV	F$	PV			F$	PV	
1	2,000	1,818	250	227	1,000	953	2,998	1,439	667	606	2,045
2	2,000	1,653	250	207	1,000	867	2,727	1,309			1,309
3	2,000	1,503	250	188	1,000	788	2,479	1,190			1,190
4	2,000	1,366	250	171	1,000	716	2,253	1,081			1,081
5	2,000	1,242	250	155	1,000	651	2,048	983			983
6			250	141	1,000	592	733	352			352
7			250	128	1,000	538	666	320			320
8			250	117	1,000	489	606	291			291
9			250	106	1,000	445	551	264			264
10			250	96	1,000	404	500	240			240
										Total	8,075

[a] Marginal tax rate is = to 48%

[b] F$ = Future dollars

[c] PV = Present value

Small Business

Year	Depreciation		Property Taxes		Mid-Year Operations and Maintenance		PV Total Deductible Expense	Total Savings After Tax[d]	Investment Tax Credit at 6.67%		PV of Tax Savings at 7%
	F$	PV	F$	PV	F$	PV			F$	PV	
1	3,600	3,273	250	227	1,000	953	4,453	980	667	606	1,586
2	1,600	1,322	250	207	1,000	867	2,396	527			527
3	1,600	1,202	250	188	1,000	788	2,178	479			479
4	1,600	1,093	250	171	1,000	716	1,980	436			436
5	1,600	993	250	155	1,000	651	1,799	396			396
6			250	141	1,000	592	733	161			161
7			250	128	1,000	538	666	147			147
8			250	117	1,000	489	606	133			133
9			250	106	1,000	445	551	121			121
10			250	96	1,000	404	500	110			110
										Total	4,096

[d] Marginal tax rate is equal to 22%

This sizable difference is caused by a disparity in marginal tax rates for the two businesses. A business earning more than $50,000 net annually has a 48 percent tax rate, while the small business has a 22 percent rate. This 26 percent variation has considerable impact.